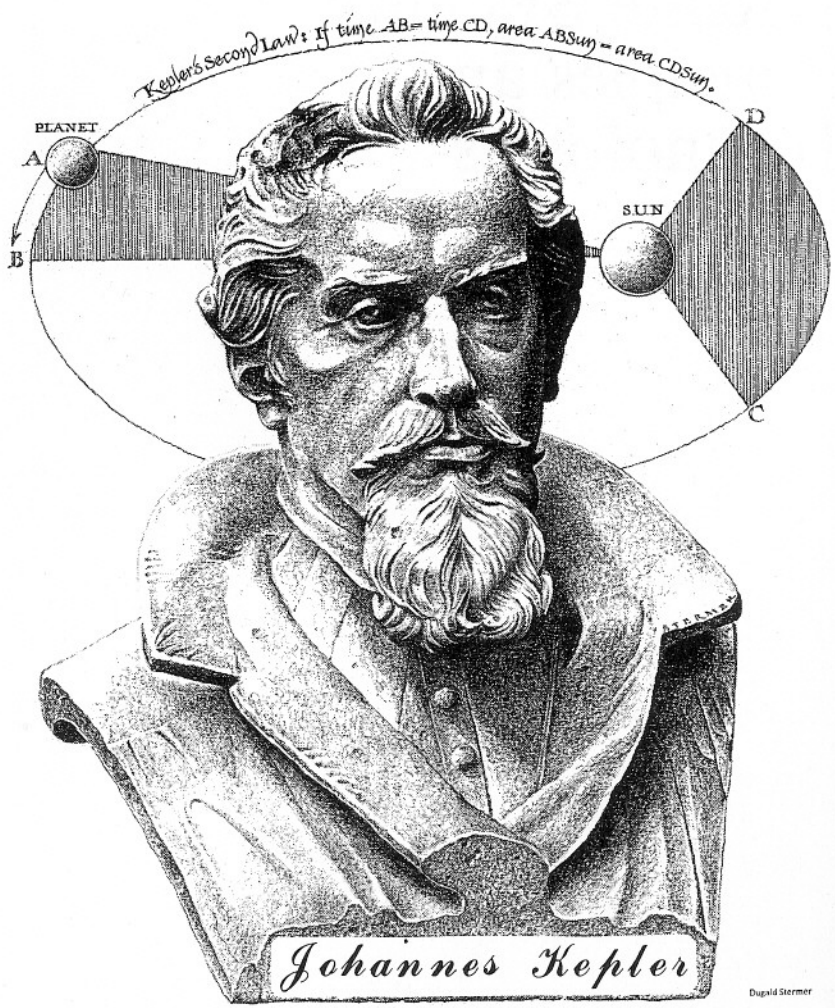
EXHIBIT B



Satellite Systems: Principles and Technologies

Bruno Pattan

Senior Member of the Technical Staff
Federal Communications Commission
Office of Engineering and Technology

VNR VAN NOSTRAND REINHOLD
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Contents

The last fundamental revision to the allocation table was made at the 1992 WARC held in the spring of 1992. Prior to that, several specialized WARCs have been held and changes have been made to the table. For example, a MOBILE WARC held in 1987, made changes to frequencies used for the mobile satellite service (MSS). The WARC-92 has made additional changes to the frequency allocations.

TYPES OF SATELLITE SERVICES

A multiplicity of services are provided by both low earth orbit and high altitude satellites. The ITU has indicated 17 possible services and these are indicated in Table 13-1. Many of the services have evolved over the years as the technology improved and rockets became available to loft heavier spacecraft to higher altitudes. Additional impetus to broaden the services was occasioned because of the requirement to communicate on a global scale. The service which has found by far the greatest application has been the Fixed Satellite Service (FSS). The services manifest a mix of frequencies, orbit altitudes, and inclinations. Clearly, where high resolution of global features is required, low earth orbits are used. Other services use polar orbits.

The ITU has allocated various parts of the spectrum to these services. Clearly, the assignments are not arbitrary and the choice of frequency for each service depends on many factors (usually designated by the user). These include

- Propagation considerations
- Service coverage (sectional, regional, global)
- Bandwidth required (greater bandwidth available at higher frequencies)
- Other users in the band selected (possibility of interference)
- Component availability
- Cost.

The process of allocating spectrum to a particular service, especially a new one, is a very lengthy procedure which may take many years and is sometimes very expensive to all parties (administrations) concerned.

The heaviest users of the spectrum are the Fixed Satellite Service (FSS), the Mobile Satellite Service (MSS) (including land, aeronautical and maritime), and the Broadcasting Satellite Service (BSS). The mobile satellite service is currently used extensively by INMARSAT for maritime services, while land and aeronautical are new INMARSAT services which are coming to fruition in the same band. The 1987 Mobile WARC has allocated a part of the spectrum for these new services. The Broadcasting Satellite Service is

TABLE 13-1. Space services provided by low and high orbit satellites

1. *Aeronautical Mobile-Satellite Service*: A mobile-satellite service in which mobile earth stations are located on board aircraft; survival craft stations and emergency position-indicating radiobeam stations may also participate in this service.
2. *Aeronautical Radionavigation-Satellite Service*: A radionavigation-satellite service in which earth stations are located on board aircraft.
3. *Amateur-Satellite Service*: A radiocommunication service using space stations on earth satellites for the same purposes as those of the amateur service.
4. *Broadcasting-Satellite Service*: A radiocommunication service in which signals transmitted or retransmitted by space stations are intended for direct reception by the general public.
5. *Earth Exploration-Satellite Service*: A radiocommunication service between earth stations and one or more space stations, which may include links between space stations.
6. *Fixed-Satellite Service*: A radiocommunication service between earth stations at specified fixed points when one or more satellites are used; in some cases this service includes satellite-to-satellite links, which may also be effected in the inter-satellite service; the fixed-satellite service may also include feeder links for other space radiocommunication services.
7. *Inter-Satellite Service*: A radiocommunication service providing links between artificial earth satellites.
8. *Land Mobile-Satellite Servce*: A mobile-satellite service in which mobile earth stations are located on land.
9. *Maritime Mobile-Satellite Service*: A mobile-satellite service in which mobile earth stations are located on board ships; survival craft stations and emergency position-indicating radiobeacon stations may also participate in this service.
10. *Maritime Radionavigation-Satellite Service*: A radionavigation-satellite service in which earth stations are located on board ships.
11. *Meteorological-Satellite Service*: An earth exploration-satellite service for meteorological purposes.
12. *Mobile-Satellite Service*: A radiocommunication service:
    - between mobile earth stations and one or more space stations, or between space stations used by this service; or
    - between mobile earth stations by means of one or more space stations.

    This service may also include feeder links necessary for its operation.
13. *Radiodetermination-Satellite Service*: A radiocommunication service for the purpose of radiodetermination involving the use of one or more space stations.
14. *Radionavigation-Satellite Service*: A radiodetermination-satellite service used for the purpose of radionavigation.
    This service may also include feeder links necessary for its operation.
15. *Space Operation Service*: A radiocommunication service concerned exclusively with the operation of spacecraft, in particular space tracking, space telemetry and space telecommand.
    These functions will normally be provided within the service in which the space station is operating.
16. *Space Research Service*: A radiocommunication service in which spacecraft or other objects in space are used for scientific or technological research purposes.
17. *Standard Frequency and Time Signal-Satellite Service*: A radiocommunication service using space stations on earth satellites for the same purposes as those of the standard frequency and time signal service.
    This service may also include feeder links necessary for its operation.

currently most used in Europe, Japan and the C.I.S. Japan was the first to experiment with this service with their BSE satellite and the C.I.S. has been providing this service via the Ekran system. Europe has recently launched several BSS satellites providing service to Europe. BSS is also referred to as the Direct Broadcasting Satellite (DBS). The U.S.A. has licensed several companies to launch satellites and to provide services to homes or communities, but has not launched one to date. There are two factors that make DBS viable, an adequate customer base and adequate financial resources, since this is a very expensive endeavor (which is generally true for any venture into the satellite business). As an example, a single satellite may cost in the range of $100 million dollars and provision of a multi-channel service to millions of homes across the U.S.A. will cost upwards of $500 million dollars.

Other services which are finding increased use of the spectrum suitable for satellites include navigational and earth remote sensing satellites. The former includes the Global Positioning System (GPS), the C.I.S.'s Glasnoss, European Navsat, and in the latter category, Meteosat (weather), NOAA (weather), and LANSAT (earth resources). Other services, such as space research and amateur use slivers of the spectrum frequently only for short periods of time, are accommodated relatively easily.

Project SCORE, which included the first communications satellite, used frequencies in the VHF band (132 MHz for the downlink and 150 MHz for the uplink). Subsequent communications satellites starting with Project Courier used frequencies above 1,000 MHz, which is generally assumed to be the separation point between UHF and microwave. For performance reasons, microwave has become the preferred band for satellite communications. One reason, of course, is that the antenna beams produced by the satellites and earth stations are confined to limited sector angles, which in turn permit larger power flux densities. In addition, this also confines the radiated power and reduces inter-satellite network interference. Probably that which should be at the top of the list is the wider bandwidths which are available at microwave frequencies in comparison with those that are available at lower frequencies. The mobile satellite service (MSS), which includes the land mobile satellite service (LMSS), the maritime mobile satellite service (MMSS), and the aeronautical mobile satellite service (AMSS), has been allocated a part of the spectrum by the ITU. Currently, the greatest activity is in the 1.5–1.6 GHz band where INMARSAT provides a maritime service. Land mobile and aeronautical mobile services are receiving increased attention by several administrations and these will be available by the early 1990s. Some tests are now being performed.

ITU FREQUENCY ALLOCATIONS FOR MOBILE SATELLITE SERVICE

A list of the bands in which allocations have been made for mobile satellite service for Region 2, including worldwide, is given in Table 13-2. The entries are from the Final Acts of the 1979 WARC and the Mobile WARC held in 1987. A U.S.A. licensee has been granted approval to provide land mobile satellite service in the band 14.0–14.5 GHz on a secondary basis for uplinking. This is coupled with downlink operation in the band 11.7–12.2 GHz and also on a secondary basis. The primary use of these bands in the U.S.A. is for Fixed Satellite Service (FSS). Therefore, as a secondary user, the licensee cannot interfere with FSS users and must accept interference with no protection of his service.

In the 1.5–1.6 GHz band, the U.S.A. has established a domestic allocation which is at variance with the ITU Frequency Allocation. This is depicted in Figure 13-2 with conditions for the spectrum use.

The 1.5–1.6 GHz spectrum applies to the communication link between the mobile unit (vehicle, aircraft, or ship) and the satellite. Additional spectrum is required between the satellite and the control and hub station. This link is called a feeder link.

FIXED SATELLITE SERVICE FOR ITU REGION 2

The frequency band allocations in the U.S.A. for the Fixed Satellite Service are indicated in Table 13-3 [4]. The ITU Radio Regulations define FSS as "A radiocommunication service between earth stations at specified fixed points when one or more satellites are used; in some cases this service includes satellite-to-satellite links, which may also be effected in the inter-satellite service, the FSS may also include feeder links for other space radiocommunications services."

Note that many of the frequencies used for FSS are also shared with other services. In order to avoid interference to terrestrial services, the satellite downlink has power flux density limitations imposed on the incident beam at the earth's surface. The incident densities permitted vary from band to band and are also a function of the flux density in a particular bandwidth, typically specified for 4 kHz or 1 MHz bandwidths.

An example of the maximum power density on the earth's surface (measured in a specified bandwidth) for a part of band in Table 13.3, is as follows [9].

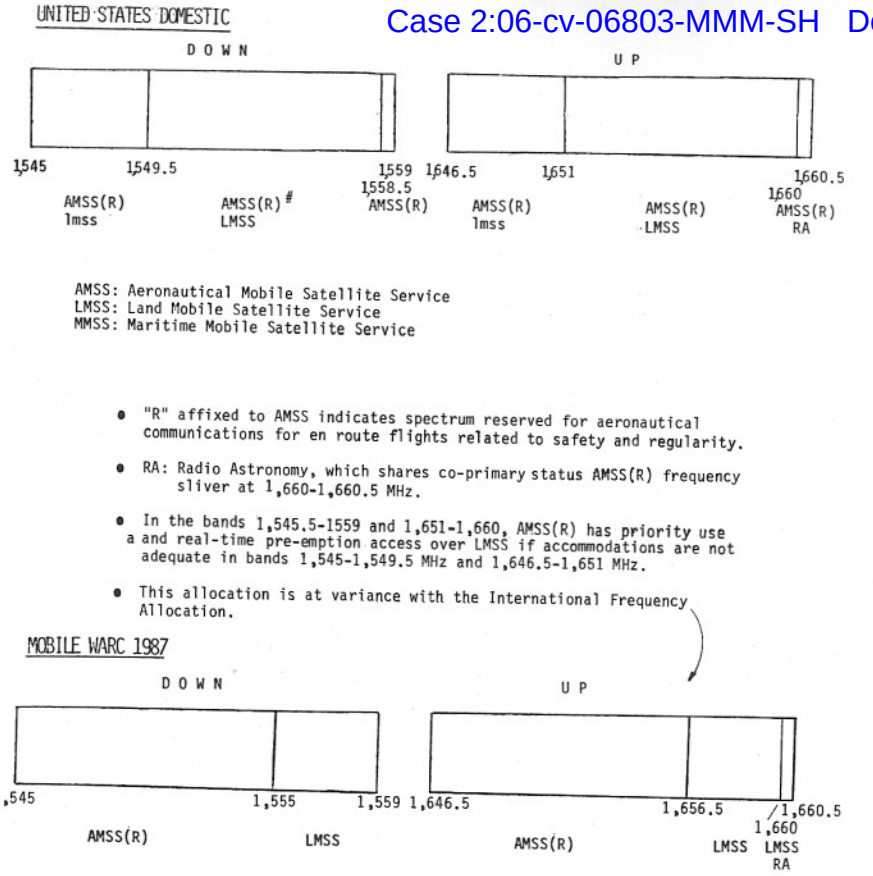

FIGURE 13-2. U.S.A. domestic and international frequency allocation for mobile satellite service (MSS).

In the band 3–8 GHz, in any 4 kHz bandwidth:

−152	dB W/m²	for $\theta \leq 5°$
$-152 + (\theta - 5)/2$		$5° < \theta \leq 25°$
−142		**25** $< \theta \leq 90°$

where θ is the angle of incident of the downlink radiation

dBW is the power with reference to one watt given in dB (e.g., 0.1 W = −10 dBW).

TABLE 13-3. Fixed satellite service frequency band allocations for the U.S.A. and ITU Region 2

Band	Direction of transmission	Primary services in addition to FSS
2,500–2,655	Down	Fixed, Mobile, Bss
2,655–2,690	Up	Fixed, Mobile, Bss
3,600–3,700	Down	Gov't Aero Radionavigation & Gov't Radio location†
3,700–4,200	Down	Fixed†
4,500–4,800	Down	Gov't Fixed & Gov't Mobile Also part of WARC'88 Allot. Plan
5,850–5,925	Up	Gov't Radiolocation
5,925–6,425	Up	Fixed
6,425–6,525	Up	Mobile and part of WARC'88 Allot. Plan
6,525–6,875	Up	Fixed and part of WARC'88 Allot. Plan
6,875–7,075	Up	Fixed and Mobile and part of WARC'88 Allot. Plan
7,250–7,300	Down	Gov't FSS and Gov't Mobile Satellite
7,300–7,450	Down	Gov't FSS and Gov't Fixed
7,550–7,750	Down	Gov't FSS and Gov't Fixed
7,900–8,025	Up	Gov't FSS and Gov't Mobile Satellite
8,025–8,175	Up	Gov't FSS, Gov't Fixed, & Gov't Earth Explore Sat.
8,175–8,215	Up	Gov't FSS, Gov't Fixed, Gov't Earth Exploration Sat. & Gov't Met. Sat.
8,215–8,400	Up	Gov't FSS, Gov't Fixed, Gov't EES
10.7–11.7 GHz	Down	Fixed-FSS Limited to Int'l Systems in U.S.A. Also part of WARC'88 Allot. Plan
11.7–12.2	Down	–
12.7–12.75	Up	Fixed & Mobile
12.75–13.25	Up	Fixed & Mobile, FSS Limited to Int'l Systems in U.S.A., also part of WARC'88 Allot. Plan
14.0–14.5	Up	–
17.3–17.7	Up	Feeder Links for BSS
17.7–17.8	Up/Down	Fixed & Mobile
17.8–18.6	Down	Fixed & Mobile
18.6–18.8	Down	Fixed, Mobile, EES, Space Res. & Gov't.
19.7–20.2	Down	Mobile Sat. is Secondary
20.2–21.2	Down	Gov't FSS & Gov't Mobile Sat.
27.5–29.5	Up	Fixed & Mobile
29.5–30	Up	–
30–31	Up	Gov't FSS & Mobile Sat.
37.5–40.5	Down	Fixed, Mobile, Mob. Sat. (39.5–40.5 GHz)
42.2–43.5	Up	Fixed, Mobile, Radio Astronomy
47.2–50.2	Up	Fixed, Mobile
50.4–51.4	Up	Fixed, Mobile
71.0–74.0	Up	Fixed, Mobile, Mob. Sat.

(*continued*)